An experimental DSB/CW QRP rig for 20 and 40 meter bands

The project in brief

The building of an HF phone rig today isn't shurely a simple job, however I'd like to propose an easy-to-make project, suited for portable or emergency use. As usual, some compromise must be accepted. Let's briefly consider good and bad points.

Strenght :

- A simple project, within most of homebrewers capabilities.
- Very simple tuning, a single stage to align, besides VFO frequency adjusting.
- Easy to find, cheap components
- Reduced dimensions and low power requirement, a totally portable rig

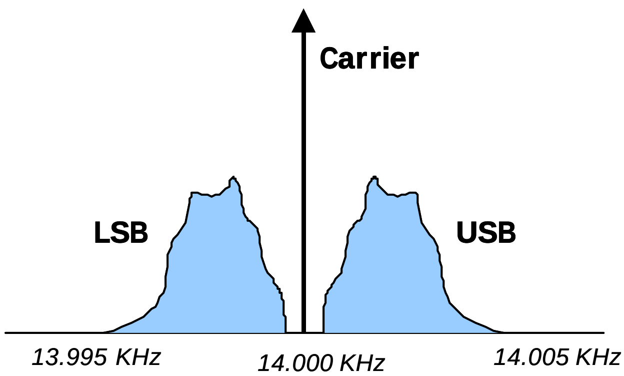
Weakness :

- DSB modulation: that is suppressed carrier and double sideband. This type of signal may be received by SSB rigs (both in LSB and USB mode) but it doubles the band width compared to an SSB signal, this should not be a problem given the low power employed (1,5 W). However the efficiency is three times higher respect to AM modulation.
- Direct conversion receiver : it performs good for SSB and CW emissions, but cannot receive DSB signals, therefore two rigs like this one cannot communicate each other in DSB. In practice an SSB rig must be located at the opposite side. The sensitivity and selectivity are those you may expect from a circuit like this one, however they seem to be adequate for the use.

I think that the project simplicity and the overall performance may well compensate theese limitations, allowing "almost" everyone to experiment with a "dual mode" rig wich, if matched to a good antenna, can operate by phone on HF bands. The described versions are suited for 40 and 20 meters bands.

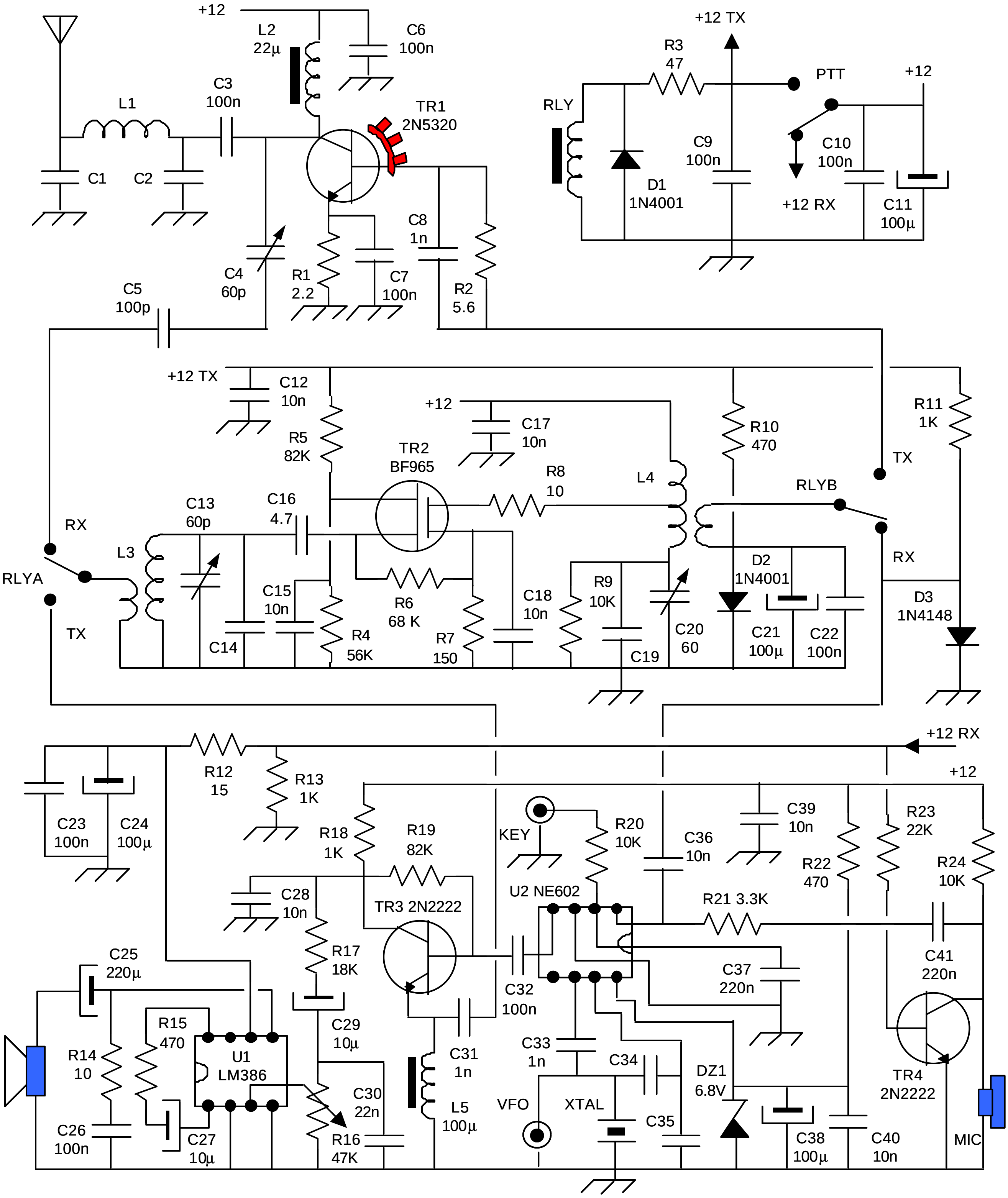
The DSB modulation

It's worth while to spend some words about the DSB modulation. It's simply a type of amplitude modulation (AM). It is common knowledge that an AM signal is composed by a carrier and two sidebands, wich take the whole information. The figure below represents an AM signal at 14.000 KHz, modulated with a 5 KHz bandwide BF signal.



It may be seen that the useful information (BF signal) may be sent by transmitting only one of the two sidebands, and this is the **SSB** principle, wich allows to optimize the efficiency and to halve the bandwidth. To produce an SSB signal we may first suppress the carrier with a balanced modulator, so as to obtain a double sided, suppressed carrier (**DSB**) signal, next the unwanted sideband may be eliminated by a narrow crystal filter. The process is somewhat complex and requires a frequency conversion system, since the DSB signal must be obtained at the fixed crystal frequency. In this project we stop at the first step of the process, using directly the DSB signal. So doing we semplify the circuit, obtaining however a good efficiency level due to the carrier suppression. A DSB signal may be received by a common SSB rig, since its IF filter is capable to cut the undesired sideband.

The RTX schematics



The receiver is a direct conversion unit. It is composed by a double tuned preselector, equipped with a BF965 mosfet, delivering a 10 dB gain, and a product detector using a "classic" NE602 [(2)] (further 18 dB of gain). A variable capacitor C4 allows to adjust the sensitivity according to the connected antenna, so we may find a right compromise to limit the effects of the strong broadcastings operating at the band edges. The detected audio is amplified by a 2N2222 transistor and an LM386 [(3)] IC delivering a few hundreds mW into an 8 Ohm speaker.

The transmitter employs the same NE602 as a balanced modulator, while TR3 (2N2222) acts as an emitter follower. The mosfet stage is now employed as a driver, with an adequate voltage applied to the gate 2, so as to raise the output signal level up to 30-40 mW. The final stage is equipped with a common 2N5320, followed by a simple Pi filter. The output power is about 1,5 W. Notice that the L2 inductor must bear the final stage current (about 200 mA) with a little voltage drop, so do not use a too little component. The mike is a fet preamplified unit, TR4 inhibits its working while in RX mode.

The TX/RX switching system uses a PTT mechanical switch wich delivers the supply voltage to RX / TX sections and drives a two exchanges micro relay. The relay switches the input and output lines in the mosfet amplifier, so allowing its double function. Notice that the mosfet's gain and power delivery are controlled by the R5 resistor on gate 2, applying the control voltage only in TX mode. So doing we can avoid overloading of the NE602 mixer in RX mode, limiting annoying interferences from broadcasting. The same voltage biases the D3 diode so as to inhibit RF signal from reaching the balanced modulator input.

The RIG may be built in two versions :

- Fixed frequency, using a crystal cut to the desired frequency (a cheap 14.318 KHz computer crystal may be used for 20 m band). In this version C34 and C35 capacitors, both 47 pF value, must be mounted.
- VFO driven (description follows in the next chapter). In this case only C35 capacitor, 1 nF value, must be mounted.

the PCB board is suited to both versions.

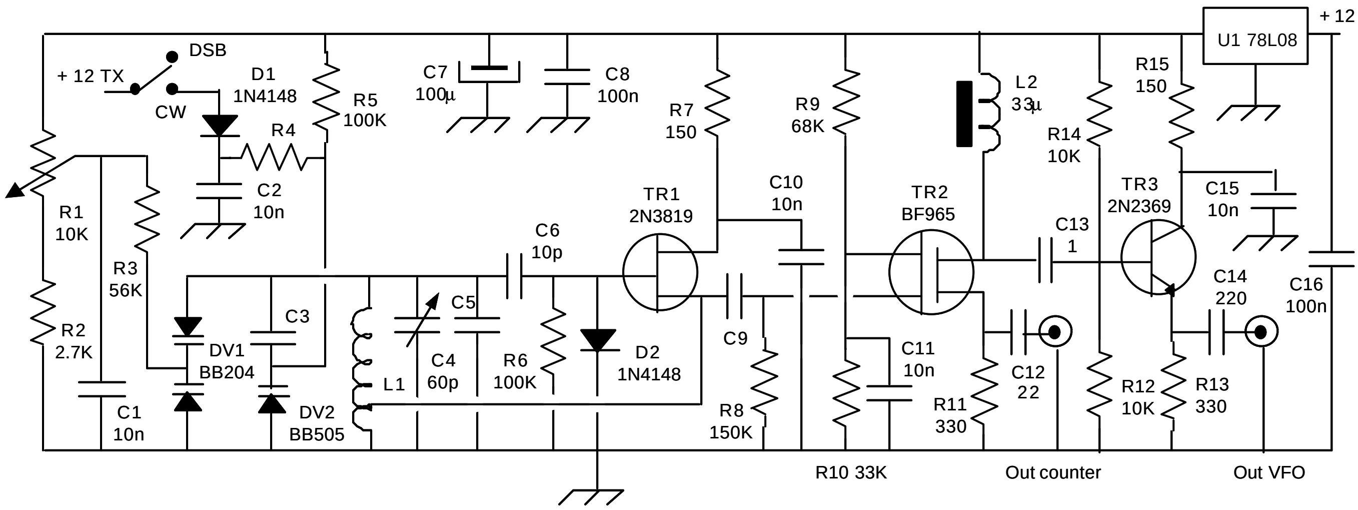
RTX components list :

C3 : 100 nF	C20 : 60 pF trimmer	C35 : see text	R9 : 10 KΩ	R24 : 10 KΩ
C4 : 60 pF trimmer	C21 : 100 µF	C36 : 10 nF	R10 : 470 Ω	TR1 : 2N5320
C5 : 100 pF	C22 : 100 nF	C37 : 220 nF	R11 : 1KΩ	TR2 : BF965
C6 : 100 nF	C23 : 100 nF	C38 : 100 µF	R12 : 15 Ω	TR3 : 2N2222
C7 : 100 nF	C24 : 100 µF	C39 : 10 nF	R13 : 1 KΩ 1/ 4W	TR4 : 2N2222
C8 : 1 nF	C25 : 220 µF	C40 : 10 nF	R14 : 10 Ω	RLY : 12 V 2 exch.
C9 : 100 nF	C26 : 100 nF	C41 : 220 nF	R15 : 470 Ω	D1 : 1N4001
C10 : 100 nF	C27 : 10 µF	R1 : 2.2 Ω 1/4 W	R16 : 47 KΩ pot.	D2 : 1N4001
C11 : 100 µF	C28 : 10 nF	R2 : 5.6 Ω	R17 : 18 KΩ	D3 : 1N4148
C12 : 10 nF	C29 : 10 µF	R3 : 47 Ω 1/4 W	R18 : 1 KΩ	DZ1 : 6.8 V - 1/2 W
C13 : 60 pF trimmer	C30 : 22 nF	R4 : 56 KΩ	R19 : 82 KΩ	U1 : LM386
C15 : 10 nF	C31 : 1 nF	R5 : 82 KΩ	R20 : 10 KΩ	U2 : NE602 / NE612
C16 : 4.7 pF	C32 : 100 nF	R6 : 68 KΩ	R21 : 3.3 KΩ	MICR: preamp. fet
C17 : 10 nF	C33 : 1 nF	R7 : 150 Ω	R22 : 470 Ω	L2 : 22 µH see text
C18 : 10 nF	C34 : see text	R8 : 10 Ω	R23 : 22 KΩ	L5 : 100 µH

- Unless different specification, all resistors should be 1/8 W (also 1/4 W units may fit the PCB), electrolytic capacitors 16 Vl. Toroid cores are from Amidon [(4)] .

Banda	C1	C2	L1	L3	C14	C19	L4
7 MHz	390 pF	270 pF	17 t. 0.5 mm on T44-6	34 t. 0.3 mm on T44-6, link 5 t. on ground side	68 pF	68 pF	34 t. 0.3 mm on T44-6, center tap, link 2 t. on ground side
14 MHz	220 pF	82 pF	12 t. 0.5 mm on T44-6	21 t. 0.4 mm on T44-6, link 4 t. on ground side	33 pF	33 pF	21 t. 0.4 mm su T44-6 center tap, link 2 t. on ground side

VFO schematics



Dealing with a direct conversion circuit, the VFO and the transmitter work on the same frequency, therefore some care must be taken to avoid interference between the two stages. I suggest to put the VFO board into a little tin-plate box (better than aluminium), avoiding to mount it too near the final TX stage.

A varicap controlled Hartley oscillator is employed. So doing we may use a multi turn potenziometer, avoiding variable capacitor and related mechanic gear. A BF965 mosfet isolates the oscillator from the output buffer, a low level signal is derived form the source to drive an external frequency meter. At last an emitter follower (TR3) is used as a buffer toward the RTX board.

To allow CW working, the +12 TX voltage is taken from RTX board and connected to a second varicap (BB505) through a DSB/CW switch. So doing we may obtain the necessary CW shift (about +800 Hz, to verify while tuning the rig).

I suggest to couple this VFO with a digital frequency reader, for example the µ-counter presented at my WEB site [(1)] , the counter must be carefully shielded to avoid pulse noise into the receiver circuit.

VFO component list :

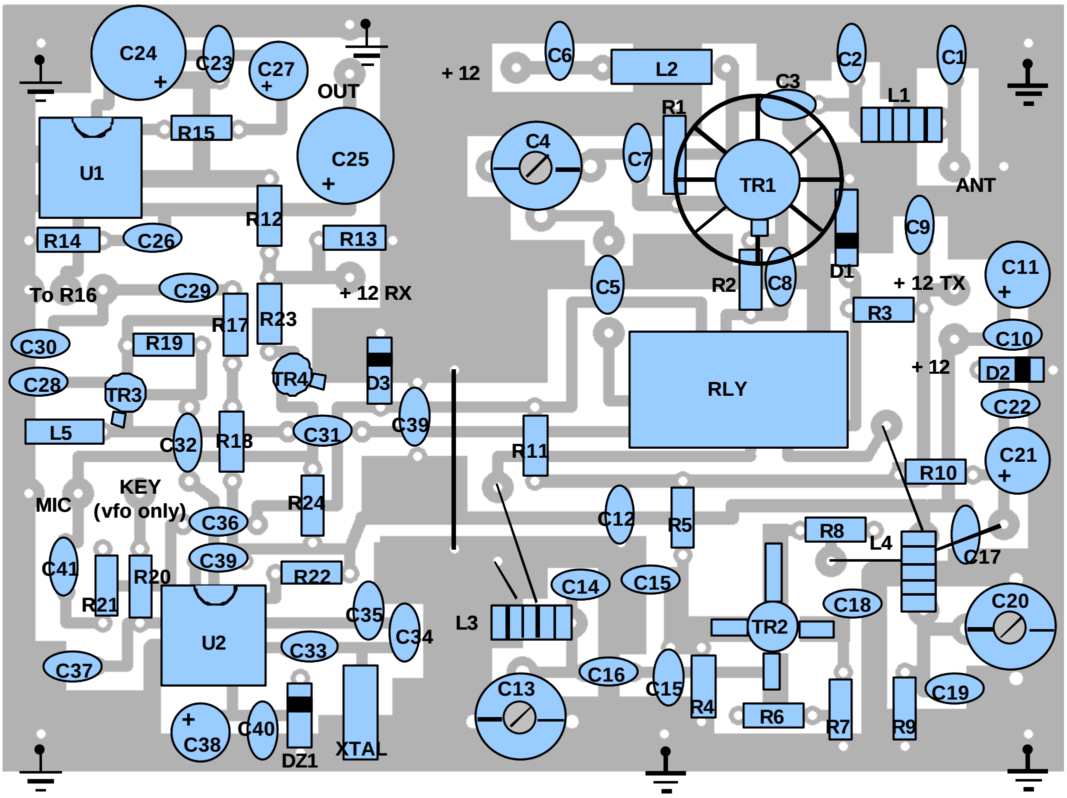
C1 : 10 nF	C14 : 220 pF	R9 : 68 KΩ	DV2 : BB505
C2 : 10 nF	C15 : 10 nF	R10 : 33 KΩ	TR1 : 2N3819
C4 : 60 pF trimmer	C16 : 100 nF	R11 : 330 Ω	TR2 : BF965
C6 : 10 pF	R1 : 10 KΩ, 10 turn pot.	R12 : 10 KΩ	TR3 : 2N2369
C7 : 100 µF	R2 : 2,7 KΩ	R13 : 330 Ω	U1 : 78L08
C8 : 100 nF	R3 : 56 KΩ	R14 : 10 KΩ	L2 : 33 µH
C10 : 10 nF	R5 : 100 KΩ	R15 : 150 Ω	
C11 : 10 nF	R6 : 100 KΩ	D1 : 1N4148	
C12 : 22 pF	R7 : 150 Ω	D2 : 1N4148	
C13 : 1 pF	R8 : 150 KΩ	DV1 : BB204	

- Unless different specification, all resistors should be 1/8 W (also 1/4 W units may fit the PCB), electrolytic capacitors 16 Vl. Toroid cores are from Amidon [(4)] .

Band	R4	C3	C5	C9	L1
7 MHz	82 KΩ	2.2 pF	330 pF NPO	2.2 pF	17 t. 0.5 mm on T50-6, tap at 5 turns from ground connection
14 MHz	220 KΩ	1 pF	120 pF NPO	1 pF	12 t. 0.5 mm on T50-6, tap at 4 turns from ground connection

RTX assembly and tuning

The RTX is assembled on a single side 110x80 mm PCB board. The figure below shows component layout (not in scale) for the crystal controlled version.



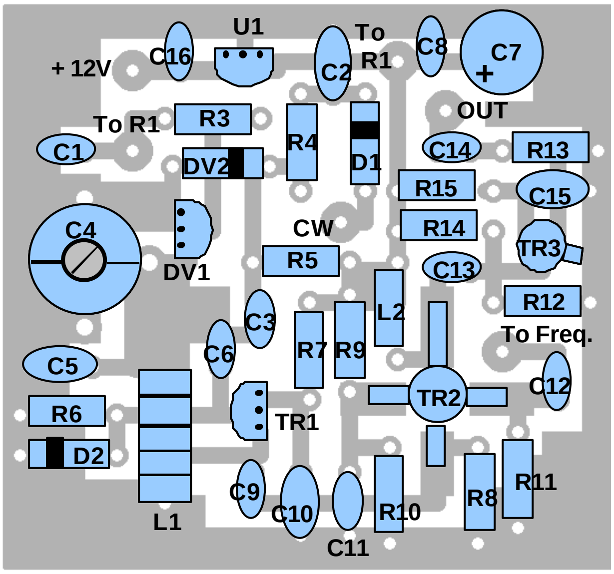
The whole circuit must be put into a metallic box to avoid humming and microphonic effect, common in direct conversion devices, for the same reason the grounding of the PCB must be effective, as shown in the drawing. Note that the TX final stage supply is kept apart from the rest of the circuit, so reducing possible RF feedback and consequent instability, for the same reason the preselector toroids are rotated 90 degrees.
The rig may be set up in the following manner :

- Tune the VFO at the center of the band, and set C4 for its maximum value.
- Ground KEY point (key down)
- Connect a 50 Ω load to TX output
- Switch the rig in TX mode and set C13 - C20 for a maximum output power. The two capacitors should be positioned on an intermediate value, otherwise a little change to C14 or C19 may be required.
- Now switch the rig in RX mode, remove the KEY connection (key up) and connect the antenna.
- Adjust C13 for the maximum sensitivity, in case of strong broadcasting interference you may adjust C4 so as to reduce the undesired signal.
- Verify the output power, it should be about 1,5 W with 300 mA input current.

No instability should arise with the reported component values. However, should the TX exhibit any tendency to self oscillate, you may reduce C16 value, or raise R5.

VFO assembly

The VFO circuit is assembled on a little, single sided, 48x45 mm PCB board. It must be enclosed into a little tin-plate box, suited for RF assembly. The figure below presents components layout (not in scale).



A + 8V stabilized output is provided to the R1 potenziometer. Also R2 resistor is located outside, directly connected to the tuning potenziometer. To tune the VFO you may use the external frequency reader, or another receiver. First you have to turn R1 all to the right (max frequency) and adjust C4, if necessary modifying C5 value, so as to tune up at the top of the band. Next turn R1 all to the left so as to read the minimum frequency, if necessary you may vary lightly R2 value. The output level toward NE602 should be about 1 V pp. At last verify the CW shift by applying a +12 V to the CW point, if necessary you may vary slightly R4 value so as to measure about +800 Hz.

CW working

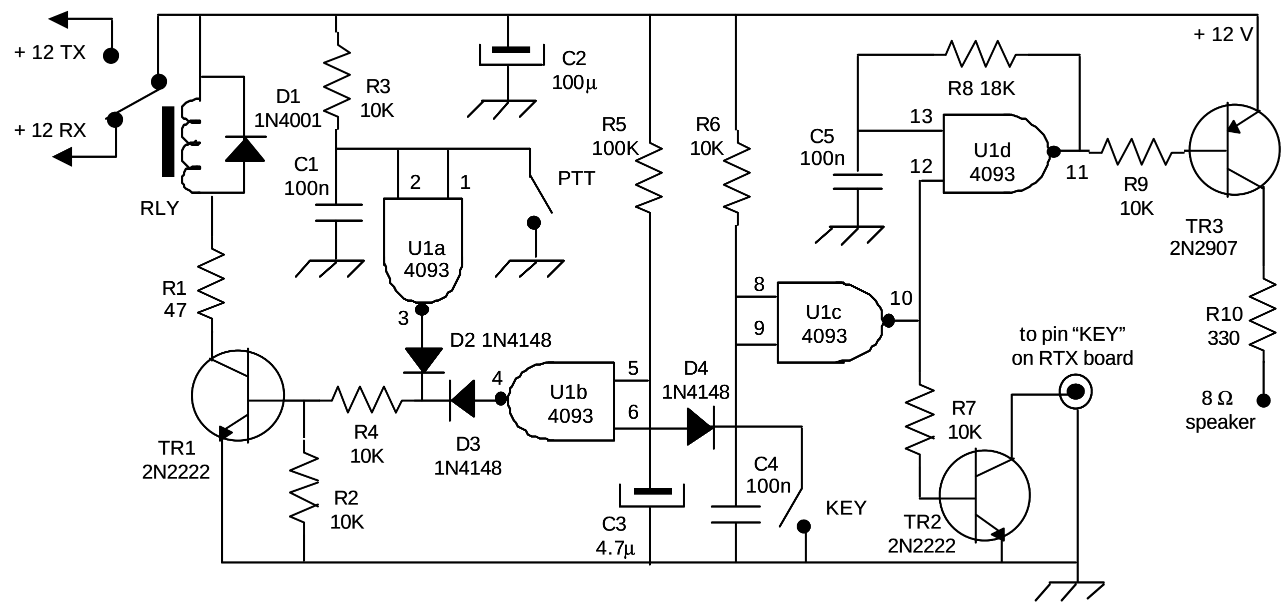
Only in the VFO version it is possible to activate CW mode. You have to connect the key to the KEY point on the RTX board and +12 TX voltage to the CW/DSB switch. To operate CW, you have to tune the received station slightly below its frequency, so as to hear the CW note at about 800 Hz. When transmitting, the VFO will automatically raise its frequency accordingly.

An optional CW module

You may add to the rig this optional CW module performing the automatic RX/TX switching and CW monitor function. The RX/TX relay is activated when you press the PTT switch, now connected to U1a gate, or when U1b gate detects a "KEY DOWN" condition, a delay circuit (R5, C3) keeps the relay "on" for about 500 mS after KEY releasing. The same "KEY DOWN" condition brings "low" the TR2 collector, wich is connected to the "KEY" pin on the RTX board, and activates the U1d oscillator, so performing the CW monitor function.

The module delivers the "+ 12 RX" e "+ 12 TX" volts to the RTX board.

CW module schematics

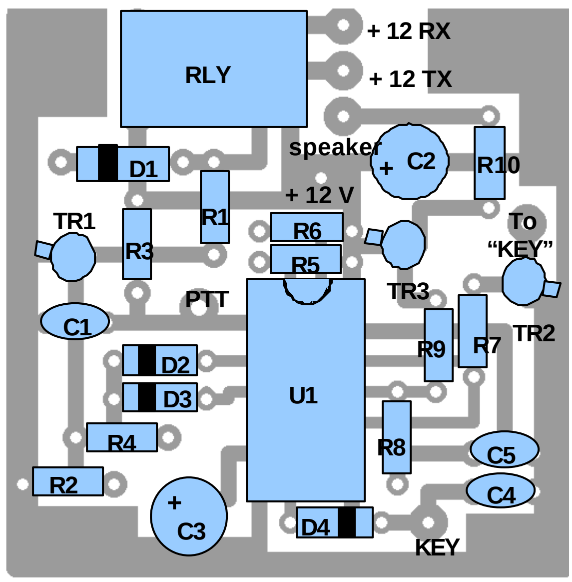


CW module components list :

C1 : 100 nF	R1 : 47 Ω	R6 : 10 KΩ	D1 : 1N4001	TR1 : 2N2222
C2 : 100 µF	R2 : 10 KΩ	R7 : 10 KΩ	D2 : 1N4148	TR2 : 2N2222
C3 : 4.7 µF	R3 : 10 KΩ	R8 : 18 KΩ	D3 : 1N4148	TR3 : 2N2907
C4 : 100 nF	R4 : 10 KΩ	R9 : 10 KΩ	D4 : 1N4148	U1 : 4093
C5 : 100 nF	R5 : 100 KΩ	R10 : 330 Ω	RLY : 12 V 1 exch.	

- Unless different specification, all resistors should be 1/8 W (also 1/4 W units may fit the PCB), electrolytic capacitors 16 Vl.

CW module assembly (single sided PCB 47 x 47 mm)



Finally

While projecting this rig I tried to achieve a simple, easy to build equipment, wich doesn't require special knowledges or tools. However you may contact me for any doubt or question at my WEB site www.qsl.net/ik3oil (where you may find other homebrewing projects) or by E-mail at my address ik3oil@arrl.net.

References

(1) PIC µCounter : a little PIC16F84 based programmable counter, see at my WEB site www.qsl.net/ik3oil

(2) NE602 Datasheet : http://www.phillipssemiconductors.com/cgi-bin/pldb/pip/NE602AD

(3) LM386 Datasheet : http://www.national.com/pf/LM/LM386.html

(4) Amidon toroidal cores : http://www.bytemark.com/products/material.htm